Insights into the Effect of Source Uncertainties on Ground Motion Simulation of the 2010 Mw7.1 Darfield Earthquake

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1) INTRODUCTION

A complete understanding of ground motion uncertainty is fundamental for physics-based seismic hazard analysis. This poster focuses on the quantification of the **effect of the earthquake source uncertainties** (fault geometry, magnitude, etc.) on the ground motion standard deviation. As a case study, the **2010 Mw7.1 Darfield** event is examined which not only illustrates a complex fault rupture case but also highlights the amount of non-uniqueness in the earthquake source model.

2) SIMULATION METHODOLOGY AND PARAMETERS

Simulation Method: Hybrid broadband approach of Graves & Pitarka (2015) which combines the low-frequency and high frequency methods at a transition frequency of f=1Hz.

Sensitivity Analyses: Examine the effect of 20 random perturbations of the reference model (Beavan 2012) for each parameter.

Uncertainty Analyses: Examine the ground motion uncertainty from varying all parameters for each proposed source model at once.

Residual Partitioning: Ground motion response spectra (pSA) residual is decomposed into between-event (δBe) and within-event (δWes) residuals:

$$\ln(Obs/Sim) = \delta Be + \delta Wes$$

3) VARIABILITY IN THE EARTHQUAKE SOURCE MODEL

Fault Dimension, Magnitude, HF Stress Parameters, Slip Distribution

Input Parameter	Perturbation Distribution	Reference Model
Magnitude, Mw	U (-0.1, 0.1)	7.1
Length, L (km)	U (-0.2L, 0.2L)	[8, 10, 16, 20, 14, 7, 11]
Width, W (km)	U (-0.2W, 0.2W)	[8, 15, 18, 18, 18, 8, 15]
Segment Rupture Init. (s)	U (-1.5, 1.5)	[NA, 5, 11, 7, 18, 18, 17]
Stress Parameter, $\Delta\sigma$ (MPa)	N (0, 10)	5

Fault Geometry

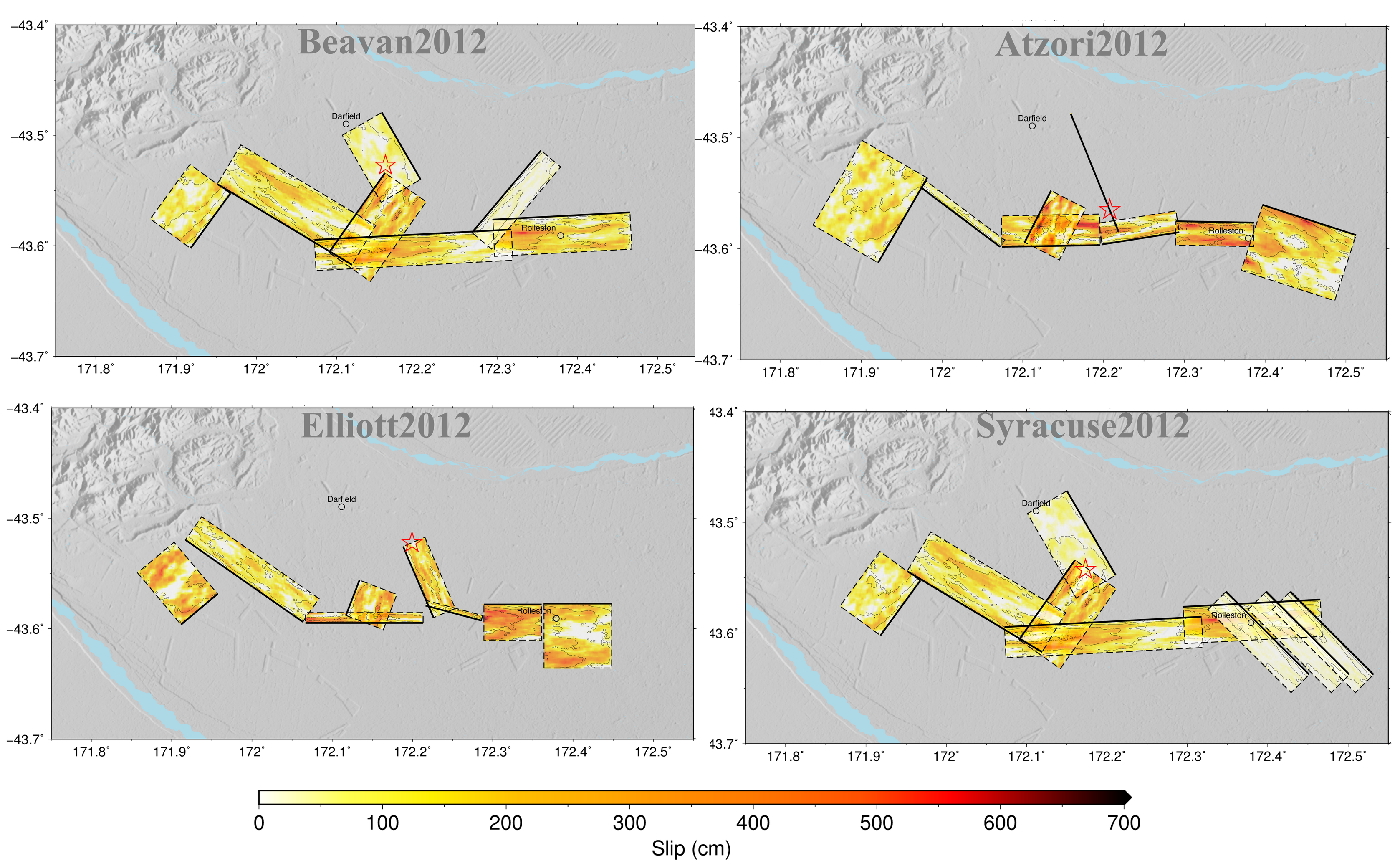

Figure 1: Adopted fault geometries for the 2010 Mw7.1 Darfield event based on four published source inversion studies; slip distribution are from random slip generator.

4) MODEL MISFIT AND SENSITIVITY ANALYSIS

PGV Spatial distribution with the pSA residuals for one slip realization of Beavan2012 source geometry

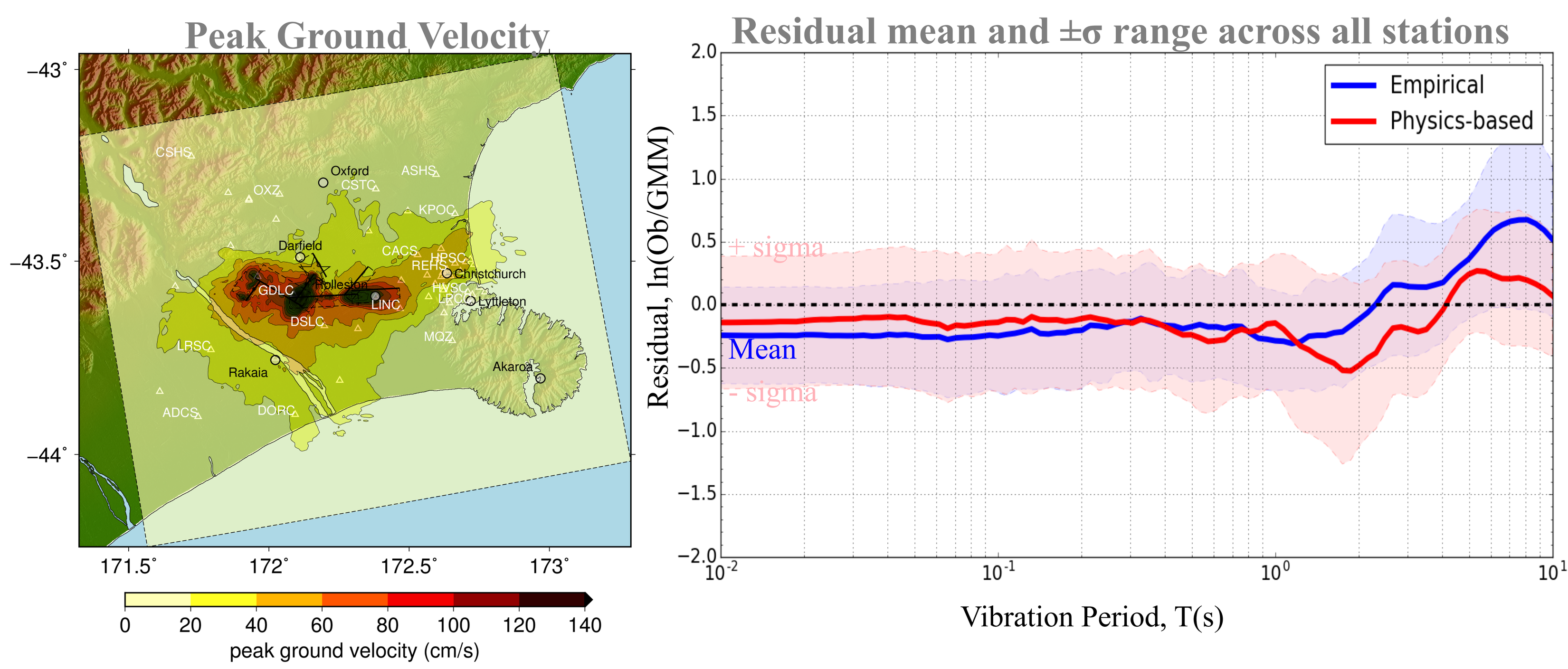

Figure 2: Simulated PGV and prediction residuals of the reference model based on Beavan et al. (2012) source model.

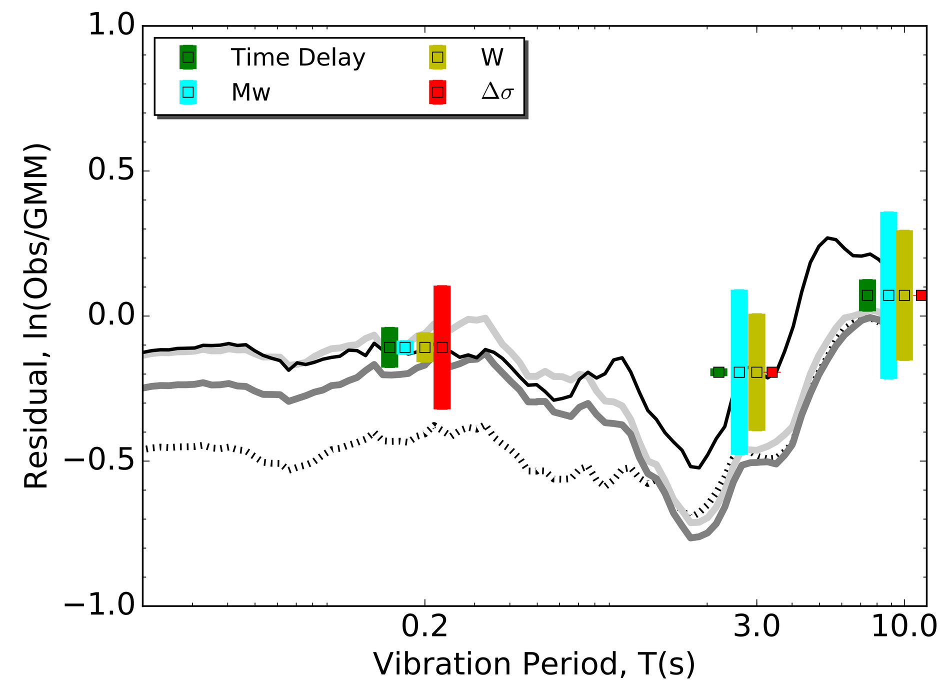

Figure 3: Sensitivity of δBe to individual parameter variations from their min and max values. Individual lines are the mean residuals for different source models

Figure 3 illustrates the variability in δBe at periods T= 0.2, 3 and 10 from varying the source parameters between their min and max values. This result suggests:

- Magnitude and $\Delta\sigma$ are the major contributors to the uncertainty at long- and short-periods, respectively.
- The effect of fault dimension is comparable to the effect of magnitude due to tradeoff between segments.
- The effect of Time delay is relatively small.

5) SIGMA PHYSICS–BASED AND EMPIRICAL MODELS

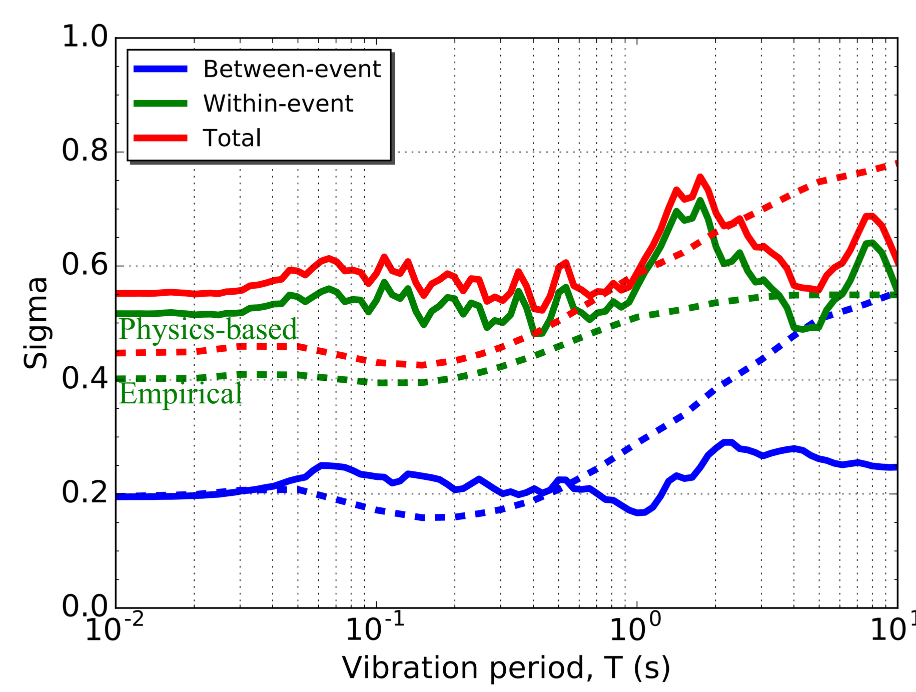

Figure 4: Within-event, between-event, and total standard deviations for ground motion simulation using the Beavan2012 source model (solid line) and empirical modeling standard deviation (dashed line).

Figure 4 shows the comparison of the within-event, between-event and total standard deviation for one of the four source models.

- Simulated standard deviation are smaller than those from empirical ground motion model for T>3s due to the incorporation of physical models.
- Significant portion of the earthquake source model uncertainty affects the betwee-event δBe, and only minor portion affects the within-event δWe (Figure not shown).

6) UNCERTAINTY ANALYSES

Standard deviation of the pSA δBe at different periods through sampling of the source parameters

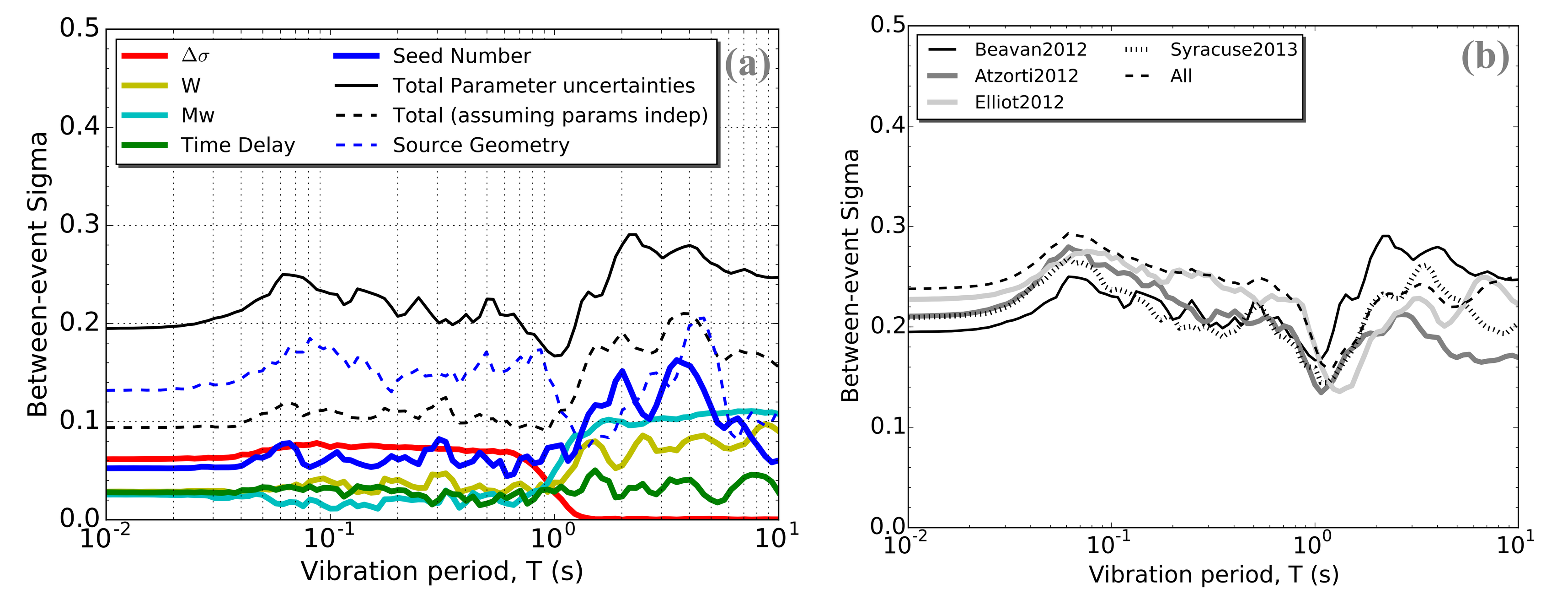

Figure 5: Standard deviation in δBe considering various seismic source uncertainties for each fault geometry: (a) individual source parameters (b) all source parameters.

Figure 5 shows the contribution of individual source parameter variability to the total uncertainty, as well as the role of the source geometry. It reveals that:

- Effect of different fault geometry is relatively large compared to the effect of individual source parameter (Fig. 5a).
- Total parameter uncertainty is mainly controlled by the variabilities in seed number (slip distribution), magnitude, and stress parameters.
- Influence of uncertainties in fault dimension and time delay is relatively constant over all periods.
- Mw and $\Delta\sigma$ uncertainty systematically increase uncertainty in the simulated pSA values at long- and short-periods, respectively, for all ground motion stations.
- Total uncertainty is larger than the uncertainty assuming independence between parameters, which suggests the need for including the correlation between parameters (e.g., magnitude-fault dimension correlation) for future analysis.

7) CONCLUSIONS

This first order uncertainty analysis of the 2010 Mw7.1 Darfield event gives a comprehensive identification of the sources of uncertainty that contribute to the total uncertainty. Our results indicate that the earthquake source model uncertainty plays a significant role only in the between-event residual portion. Hence, incorporation of other sources of uncertainties such as in the velocity model and site amplification need to be considered to acquire more understanding of the full ground motion prediction uncertainty. This study also can be extended using other events located outside the Canterbury region to examine the uniformity of the uncertainty. Ground motion simulation validation with model uncertainties also is fundamental as a step towards physics-based seismic hazard analysis.